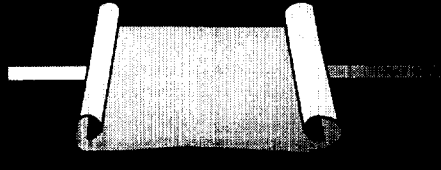
Joint CMA DOE Chemical Safety Workshop

Risk Mapping for Prioritizing Waste Management Activities at Pantex

Robert W Johnson



DOE Need:

- Pantex Waste Mgmt.
- Risk-based prioritization
- Effects of budget cuts

Chemical Industry Technology:

- Integrated costs + risks
- Scenario-based analysis

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Quantitative

Order-of-magnitude

Risk-based

Costs

Benefits

Database

Project management

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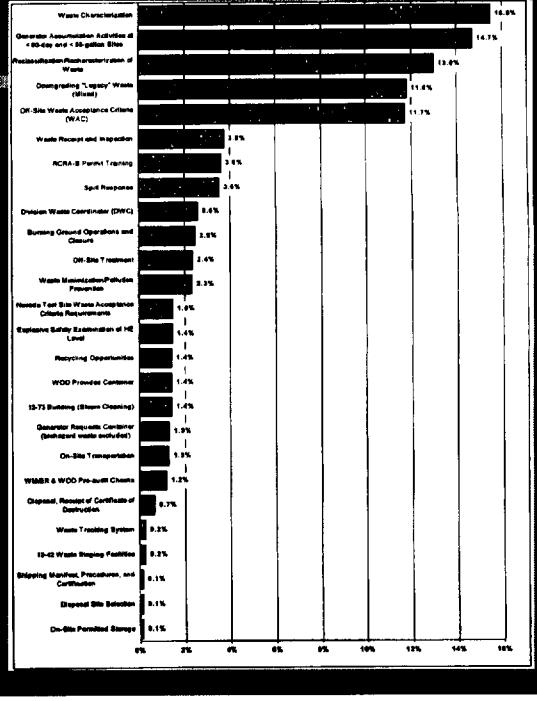
Background

A ***risk analysis*** ranks things by risk.

It shows where new resources can be spent to reduce risk.



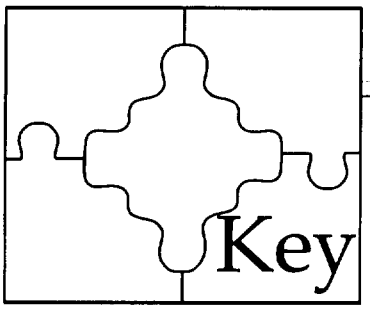
Background (continued)

Operations management also needs to know:

- the impact of *discontinuing* activities
- relative risks of proposed new projects
- how to optimize resources
- priorities for competing activities

- *Key Elements of Risk Mapping*

- *Risk Mapping Applied to Pantex Waste Management*



Key Elements of Risk Mapping

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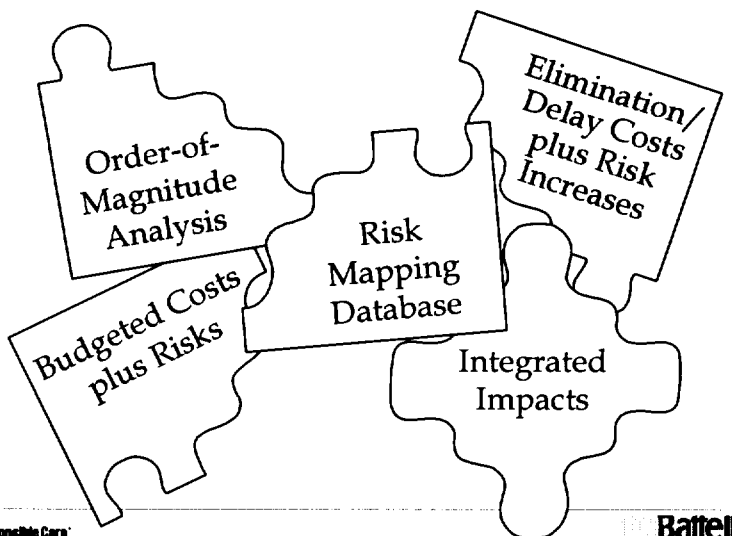
Five Key Elements



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KEY ELEMENT #1

What is the total, long-term cost of something?

- Budgeted (expected) **costs**

PLUS

- Non-budgeted liabilities that may or may not be realized ***(risks)***

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Example 1

What is the total, long-term cost of owning a home?

- Expected costs (mortgage, furnishings, utilities, maintenance, taxes, insurance)

PLUS

- Non-budgeted liabilities (unexpected repairs and expenses, uninsured losses, lawsuits, work injuries, etc.)

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Example 2

What is the total, long-term cost of chlorine water treatment?

- Expected costs (facilities, materials, operations, routine maintenance, EHS, overheads, insurance)

PLUS

- Non-budgeted liabilities (e.g., accidental chlorine release risk)

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Cost + Risk

How can *expected costs* be combined with *risks*?

- Life cycle costs + life cycle risks

OR

- Annual costs + annualized risks

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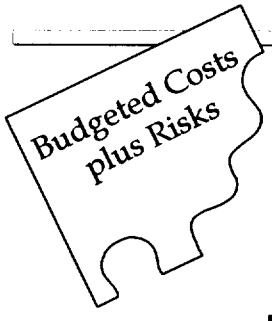
Cost + Risk



How can *expected costs* be combined with *risks*?

- Life cycle costs + life cycle risks

OR

- Annual costs + annualized risks

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Cost + Risk = ?

FY Budgeted Cost

+ Annualized Risk

Total Annual Liability

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Units of Measure

	FY Budgeted Cost	**($/yr)**
+	**Annualized Risk**	**($/yr)**
	Total Annual Liability	**($/yr)**

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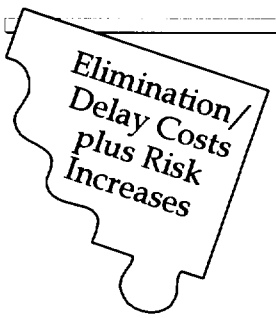
KEY ELEMENT #2



What *benefits* are provided by something?

- Budgeted (expected) **benefits**

PLUS

- Accident avoidance that may or may not be realized ***(safeguards)***

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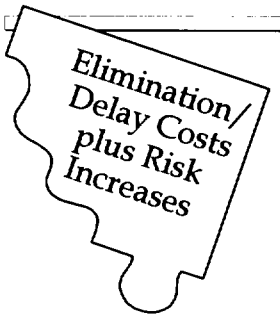
Measurement of Benefits



Benefits can be measured by determining the impact of not doing something.

- Eliminate
- Delay

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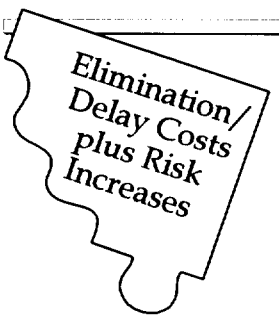
Example 1



What is the total, long-term benefit of owning a home?

- If you decide ***not*** to own a home:
  - No equity accrual
  - Loss of social/cultural benefits
- If you ***delay*** owning a home one year:
  - Same as above, with lesser impact

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Example 2

What is the total, long-term benefit of having an emergency relief system?

- If it is decided to ***eliminate*** the ERS:
  - No expected (certain) impacts
  - Increased risk of noncompliance penalties
  - Increased risk of bursting vessel explosion

  for system protected by ERS

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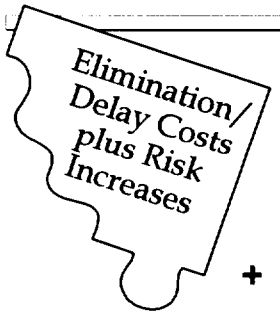
Total "Benefit"



Expected Impacts if Eliminated

+ Annualized Risk Increase

Total Liability if Eliminated

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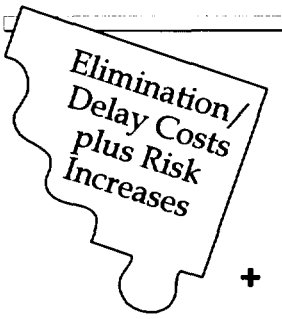
Units of Measure



Expected Impacts ($/yr)

+ Annualized Risk Increase ($/yr)

Total Liability ($/yr)

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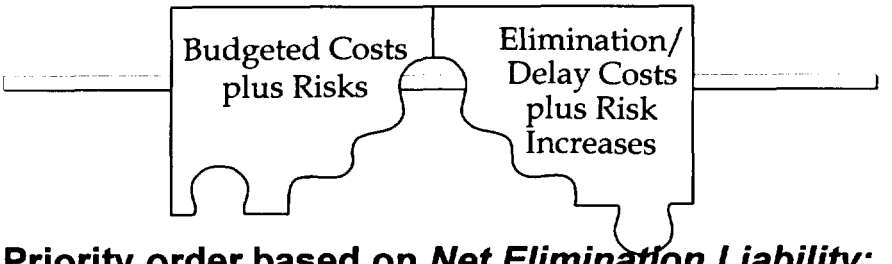

Priority order based on *Net Elimination Liability:*

- (Budgeted Costs + Risks)

+ (Elimination Costs + Risk Increases)

Net Elimination Liability

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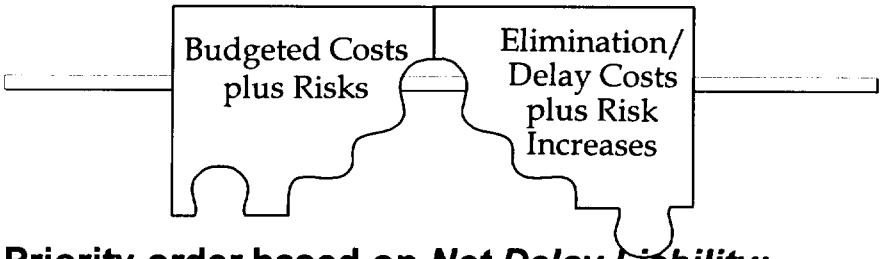

Priority order based on *Net Delay Liability:*

- (Budgeted Costs + Risks)	$/yr
+ (Delay Costs + Risk Increases)	$/yr
Net Delay Liability	$/yr

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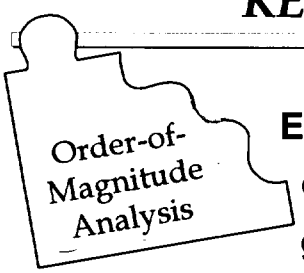
KEY ELEMENT #3



Estimating cost & risk parameters on an order-of-magnitude basis gives sufficient precision to differentiate and prioritize.

- Minimize effort
- Analyze quantitatively
- Match accuracy

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Use of Exponents

Scientific notation uses power-of-10 *exponents.*

0.01/yr x $100,000 = $1,000/yr

is the same as

10^{-2} /yr x $\$10^{5}$ = $\$10^{3}$ /yr

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Use of Exponents

Adding exponents is the same as multiplying.

$10^{(-2 + 5)} = 10^{3}$

10^{-2} /yr x $\$10^{5}$ = $\$10^{3}$ /yr

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Use of Exponents

In risk mapping, the exponent is used to represent the number.

$100,000

is represented by

5

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Use of Exponents

In risk mapping, the exponent is used to represent the number.

0.01/yr x $100,000 = $1,000/yr

is represented by

-2 + 5 = 3

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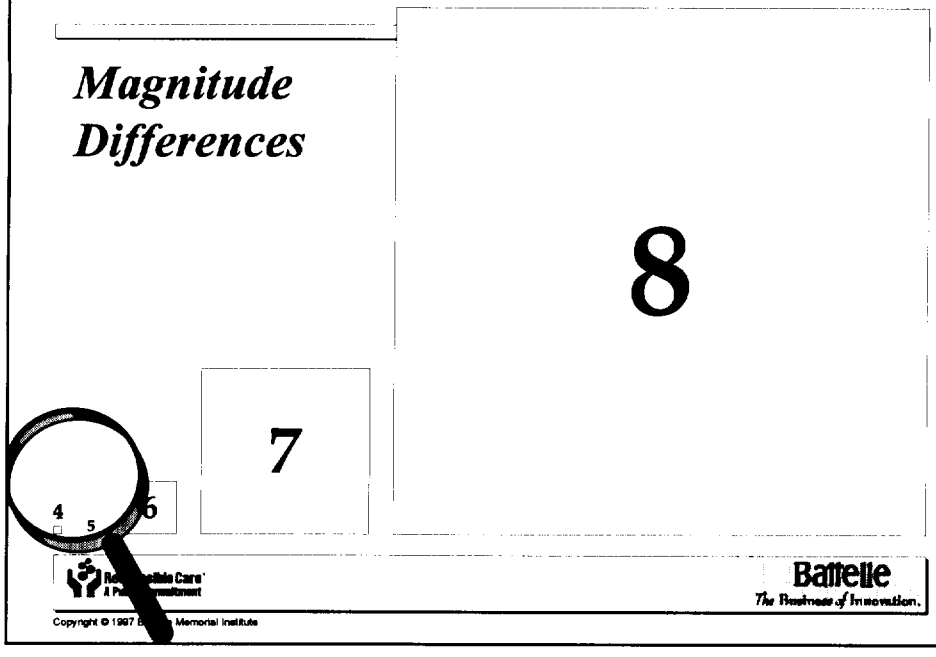
Magnitude Differences



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Tenths of a Magnitude

Greater precision is possible by using tenths of magnitudes.

$$3{,}200 = 10^{3.5}$$

10,000	**4.0**
7,900	3.9
6,300	3.8
5,000	3.7
4,000	3.6
3,200	**3.5**
2,500	3.4
2,000	3.3
1,600	3.2
1,300	3.1
1,000	**3.0**

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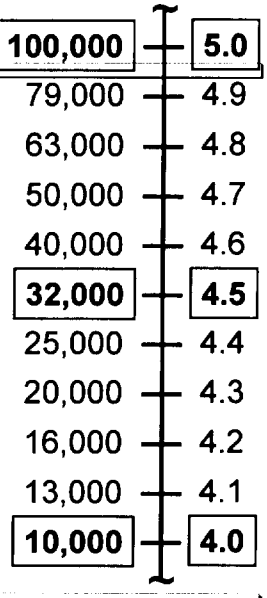
Tenths of a Magnitude

Only the decimal place changes for the next higher magnitude.



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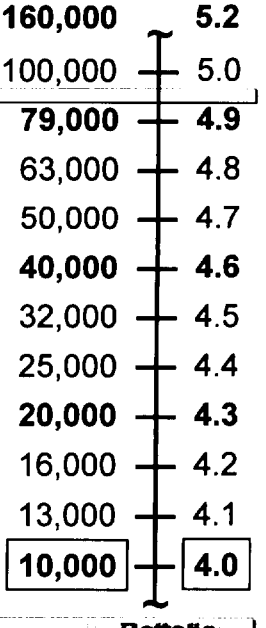
Tenths of a Magnitude

Rule of thumb:
A two-fold increase
corresponds to
~0.3 order of magnitude.



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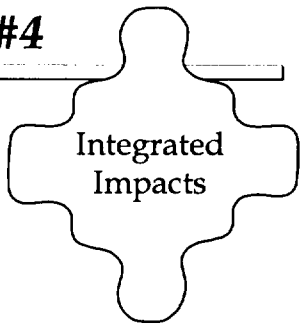
KEY ELEMENT #4



Diverse impacts must all be considered by the decision maker.

- Safety & health
- Environment
- Facilities
- Business
- Stakeholders

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Need:
A means of combining diverse impacts into a unified cost + risk picture.

Approach:
Put scales of consequence severities into a unified orders-of-magnitude framework.

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Impact Magnitudes (Simplified)

	Public S&H	Site S&H	Environ-mental	Cost, Loss, or Liability
8	Fatality or permanent health effect	Many fatalities	Widespread and long-term or permanent	$100,000,000
7		Fatality or permanent health effect		$10,000,000
6	Severe injury or multiple injuries		Widespread and short-term or localized and long-term	$1,000,000
5	Injury or hospitalization	Severe injury or multiple injuries		$100,000
4	Exposure above limits	Recordable injury	Localized and short-term	$10,000

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Impact Magnitudes

	Public S&H	Site S&H	Environ-mental	Cost, Loss, or Liability
8	**NOTE:**			$100,000,000
7	**The responsible decision makers must agree with the integrated impact table before proceeding with the risk mapping.**			$10,000,000
6				$1,000,000
5				$100,000
4				$10,000

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DOE Performance Categories

- Public Health & Safety
- Site Personnel Health & Safety
- Environmental
- Compliance
- Mission Impact
- Mortgage Reduction
- Social, Cultural, Economic

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DOE Categories: Integrated Impacts

	Public S&H	Site S&H	Env	Com-pliance	Mission Impact	Mtge Redn	Soc/ Cult/ Econ
7	PS1		EN1		MI1	MR1	
6		SP1	EN2	CO1		MR2	SO1
5	PS2	SP2		CO2	MI2		SO2
4		SP3	EN3				SO3
3	PS3				MI3		SO4
2		SP4		CO3			

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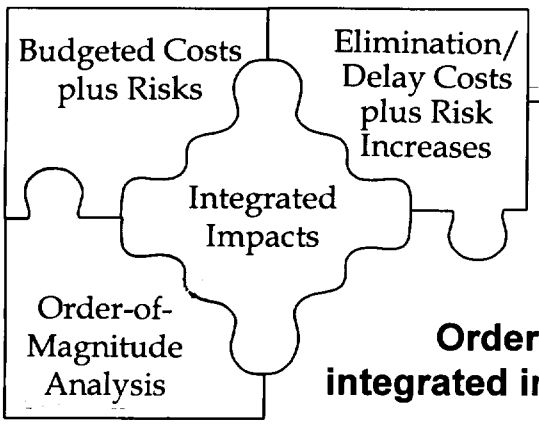
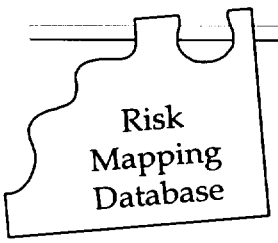


Order-of-magnitude integrated impacts are used for:

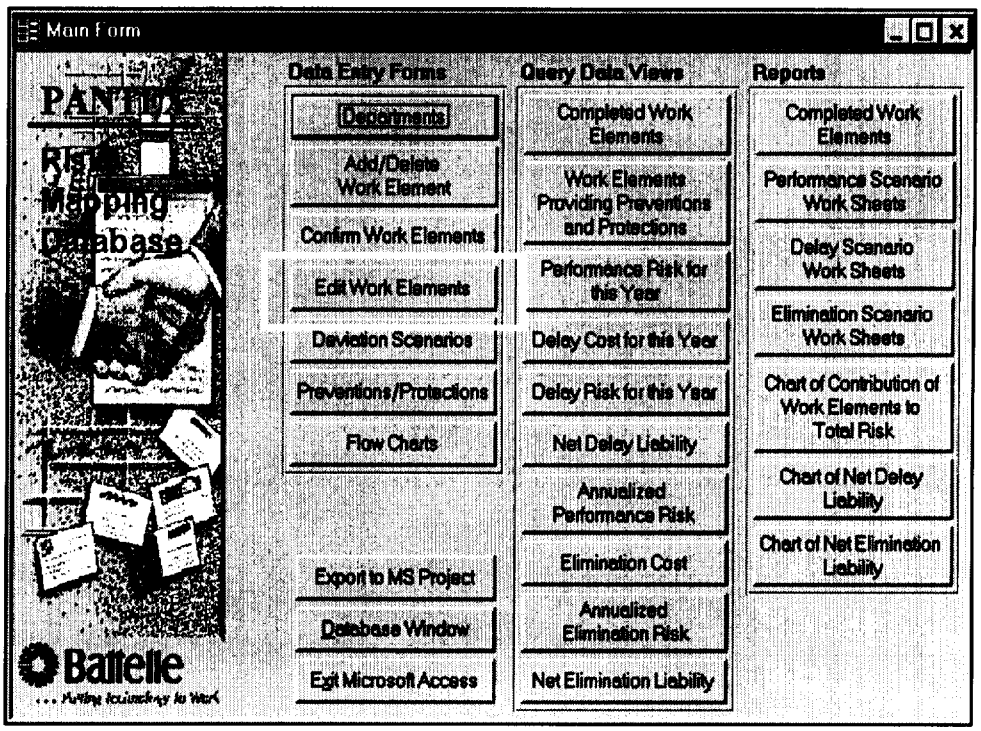
- Accident risk consequences
- Elimination and delay costs

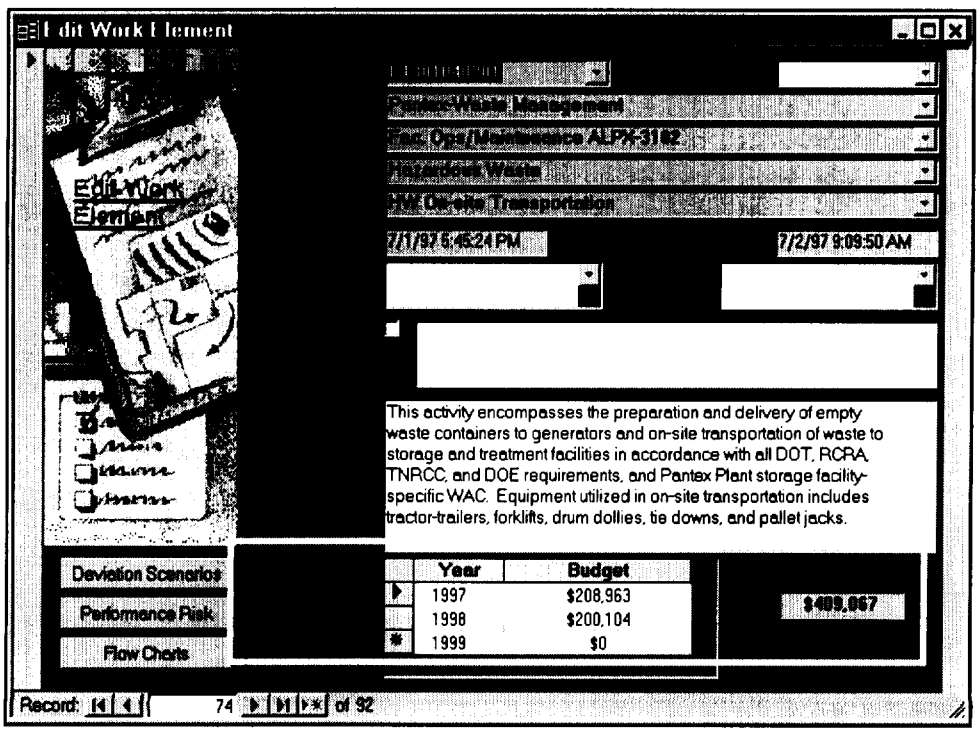
KEY ELEMENT #5

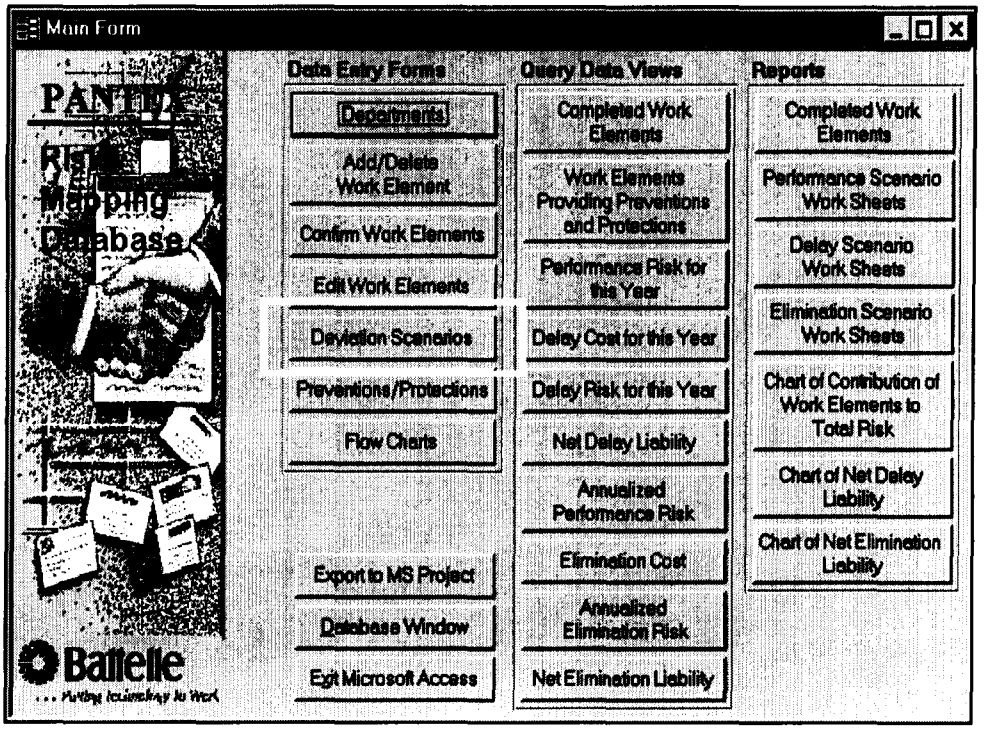


For risk mapping of Pantex Waste Management activities, all cost and risk parameters were entered into a customized Access® database.

- **Automatic risk calculations**
- **Queries and reports**


Main Form
PANTEX
Risk
Mapping
Database
Battelle
Data Entry Forms
Documents
Add/Delete Work Element
Confirm Work Elements
Edit Work Elements
Deviation Scenarios
Preventions/Protections
Flow Charts
Export to MS Project
Database Window
Exit Microsoft Access
Query Data Views
Completed Work Elements
Work Elements Providing Preventions and Protections
Performance Risk for this Year
Delay Cost for this Year
Delay Risk for this Year
Net Delay Liability
Annualized Performance Risk
Elimination Cost
Annualized Elimination Risk
Net Elimination Liability
Reports
Completed Work Elements
Performance Scenario Work Sheets
Delay Scenario Work Sheets
Elimination Scenario Work Sheets
Chart of Contribution of Work Elements to Total Risk
Chart of Net Delay Liability
Chart of Net Elimination Liability


Edit Work Element
7/1/97 6:46:24 PM
7/2/97 9:09:50 AM
This activity encompasses the preparation and delivery of empty waste containers to generators and on-site transportation of waste to storage and treatment facilities in accordance with all DOT, RCRA, TNRCC, and DOE requirements, and Pantex Plant storage facility-specific WAC. Equipment utilized in on-site transportation includes tractor-trailers, forklifts, drum dollies, tie downs, and pallet jacks.
Deviation Scenarios
Performance Risk
Flow Charts
Year
Budget
1997
$208,963
1998
$200,104
1999
$0
$409,067
Record: 74 of 92


Main Form
PANTEX
Risk Mapping Database
Battelle
Data Entry Forms
Departments
Add/Delete Work Element
Confirm Work Elements
Edit Work Elements
Deviation Scenarios
Preventions/Protections
Flow Charts
Export to MS Project
Database Window
Exit Microsoft Access
Query Data Views
Completed Work Elements
Work Elements Providing Preventions and Protections
Performance Risk for this Year
Delay Cost for this Year
Delay Risk for this Year
Net Delay Liability
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Elimination Cost
Annualized Elimination Risk
Net Elimination Liability
Reports
Completed Work Elements
Performance Scenario Work Sheets
Delay Scenario Work Sheets
Elimination Scenario Work Sheets
Chart of Contribution of Work Elements to Total Risk
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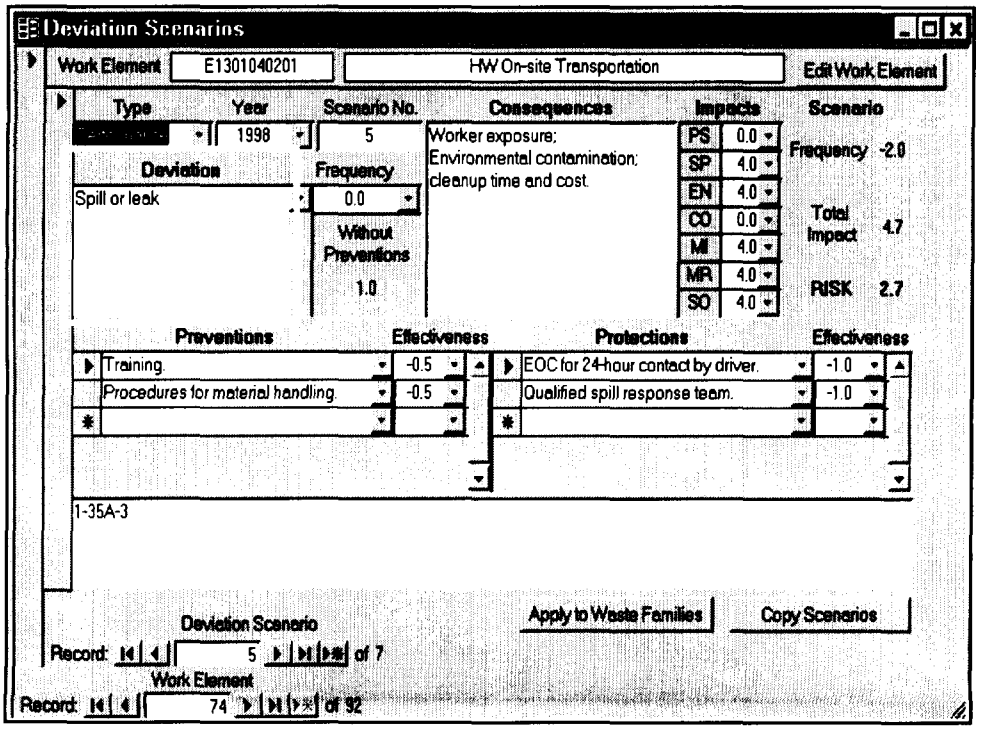
Chart of Net Elimination Liability


Deviation Scenarios
Work Element
E1301040201
HW On-site Transportation
Edit Work Element
Type
Year
1998
Scenario No.
5
Consequences
Worker exposure; Environmental contamination; cleanup time and cost.
Impacts
PS 0.0
SP 4.0
EN 4.0
CO 0.0
MI 4.0
MR 4.0
SO 4.0
Scenario
Frequency -2.0
Total Impact 4.7
RISK 2.7
Deviation
Spill or leak
Frequency
0.0
Without Preventions
1.0
Preventions
Effectiveness
Training.
-0.5
Procedures for material handling.
-0.5
Protections
Effectiveness
EOC for 24-hour contact by driver.
-1.0
Qualified spill response team.
-1.0
1-35A-3
Deviation Scenario
Record: 5 of 7
Apply to Waste Families
Copy Scenarios
Work Element
Record: 74 of 92

Project Management

Risk Mapping Database

The risk mapping database fields are based on a MS Project® task structure.

- **Share budgeted cost information**
- **Eliminate or delay a task: automatically update task structure**

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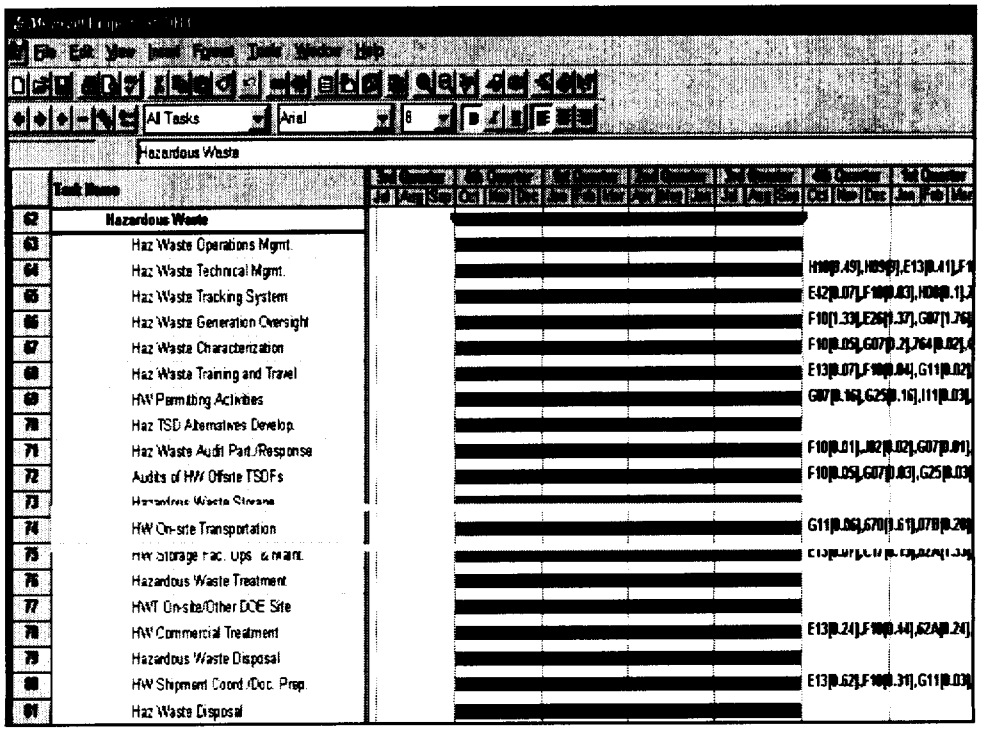

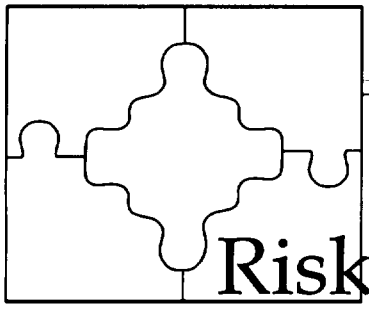

Risk Mapping Applied to Pantex Waste Management

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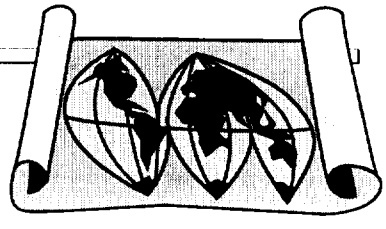
Risk Map



MODEL

ANALYZE

PLAN

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Risk Map

- *MODEL:* **Define work elements; agree on baselines**
- *ANALYZE:* **Cost and risk factors**

Performance Cost	Performance Risk
Delay Cost	Delay Risk
Elimination Cost	Elimination Risk

- *PLAN:* **Use results for cost/risk-based decisions**

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MODEL

ANALYZE

PLAN

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MODEL

Activities must be broken down to the level at which risk/$ decisions are made.

Program	Dept	ADS	Project	Activity
Pantex	WM/ER	WM	A0001	Shipping Coord.
			A0002	LLW Treatment
	Weapons		A0003	LLW Disposal
	Support	E R		

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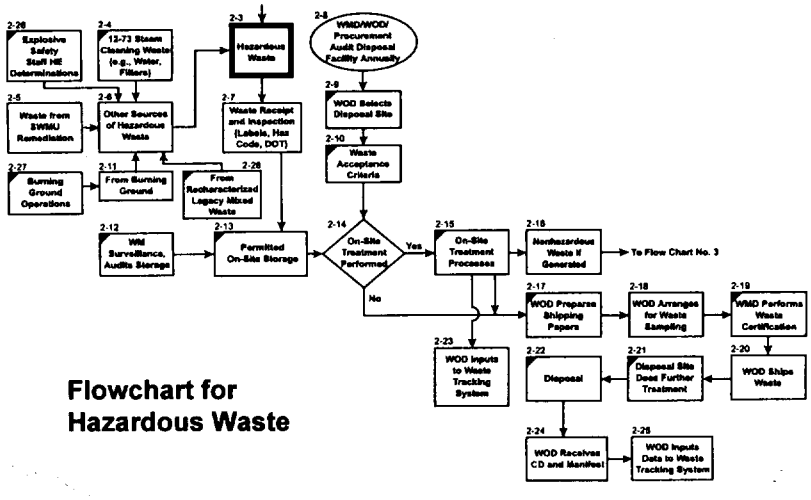
Flowchart Model for Pantex WM



Flowchart for Hazardous Waste

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MODEL

ANALYZE

PLAN

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Ground Rules

- **Actual costs, not bounding cases**
- **Best-estimate risks, not worst cases**
- **Order-of-magnitude estimates OK**
  - Better to be accurate than to be precise
  - Don't spend time getting more precise than 2x to 3x
- **Aim for highest-risk scenarios**
  - Highest combined likelihood and severity
  - Will not have exhaustive set of scenarios

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Risk Mapping Factors

WORK ELEMENT *e.g.*, Waste Treatment	
	Performance Cost
	Performance Risk
	Delay Cost
	Delay Risk Increase
	Elimination Cost
	Elim. Risk Increase

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Performance Cost

WORK ELEMENT *e.g.*, Waste Treatment	
	Performance Cost
	Performance Risk
	Delay Cost
	Delay Risk Increase
	Elimination Cost
	Elim. Risk Increase

= Budgeted cost to perform work element, by fiscal year

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Performance Risk

WORK ELEMENT *e.g.*, Waste Treatment	*Performance Cost*
	Performance Risk
	Delay Cost
	Delay Risk Increase
	Elimination Cost
	Elim. Risk Increase

= Non-budgeted liability involved in performing work, by fiscal year

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Obtaining the Performance Risk

Performance Cost
Performance Risk
Delay Cost
Delay Risk Increase

- Scenario-based risk analysis
- Best done by team review

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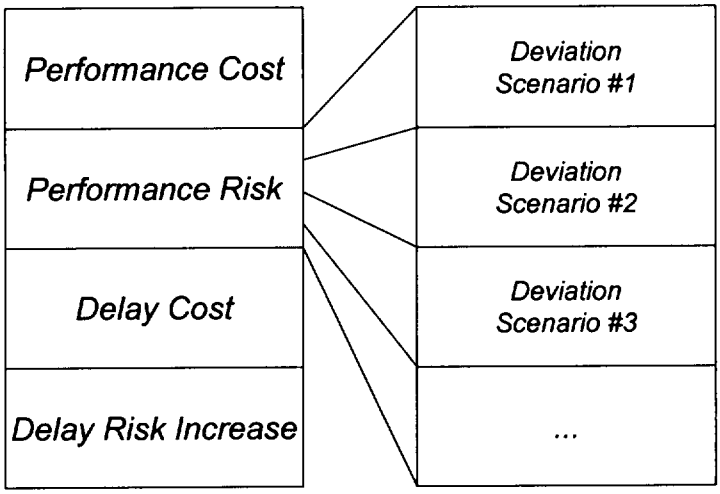
Scenario-Based Risk Analysis



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Risk

Risk combines the *frequency* and *severity* of scenario consequences of concern.

$$Risk = Frequency \times Severity$$

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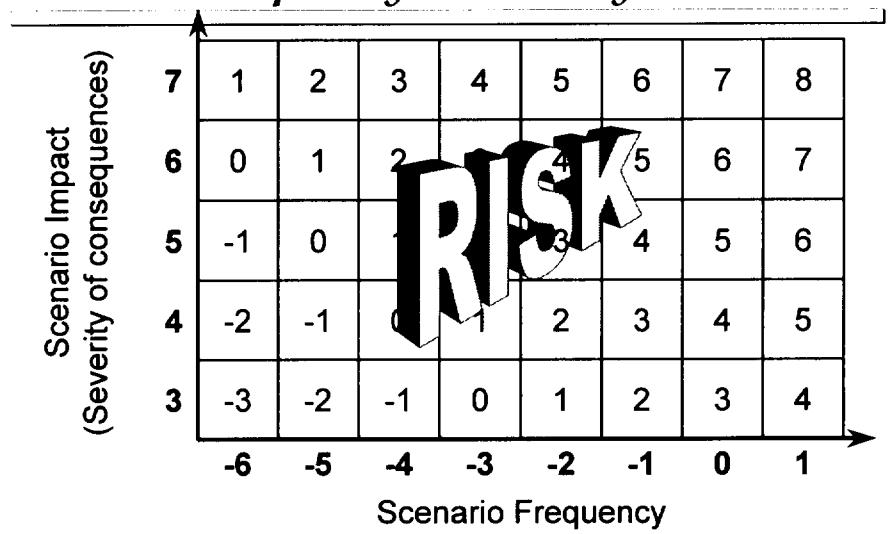
Risk = Frequency x Severity



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Scenario-Based Risk Analysis

Baseline Projects / Activities

For each activity: **Identify Deviations**

For each deviation: **Develop Scenarios**

For each scenario with consequences: **Likelihood** **Severity**

Calculate Risk

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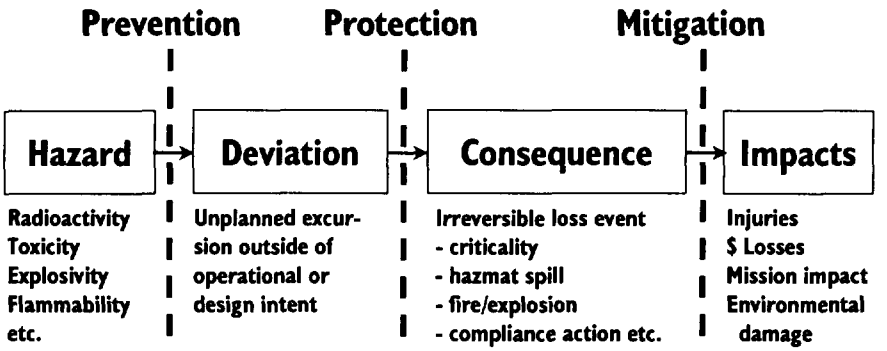
Anatomy of an Incident

Deviation scenario elements:



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1. Define the Activity Baseline

- **Design/operational intention**
- **Process parameters**
- **Equipment, procedures**

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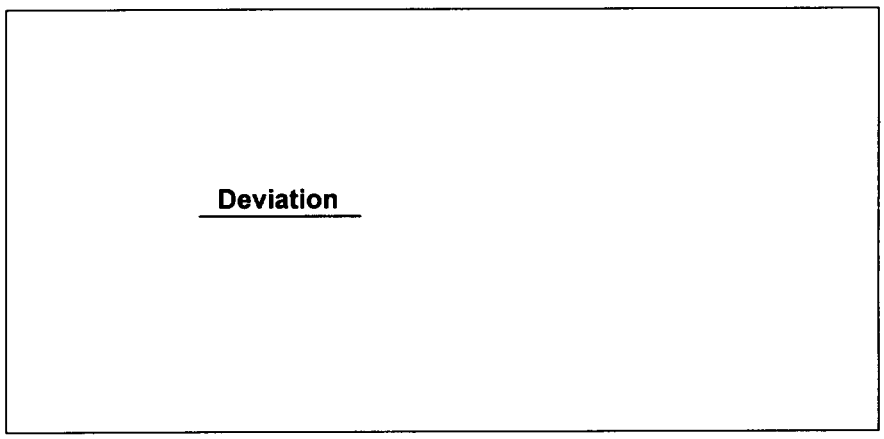
2. *Identify a Deviation from the Baseline*



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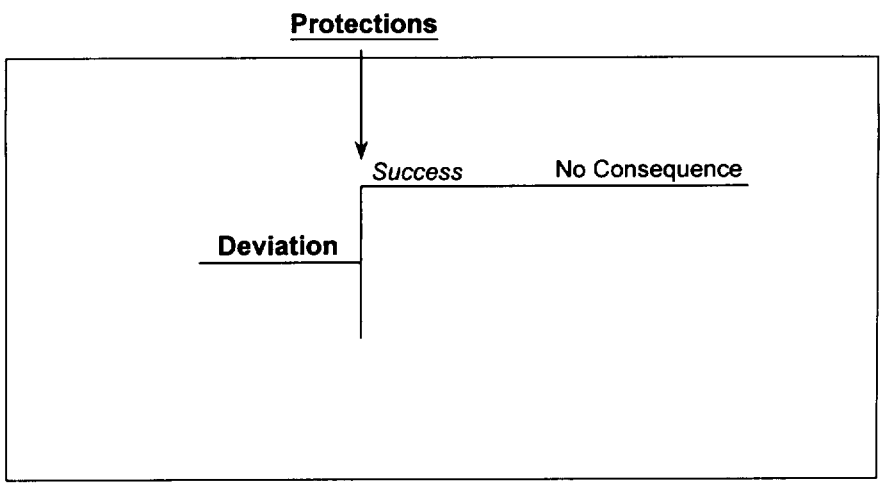
3. *Determine Protections Against the Deviation*



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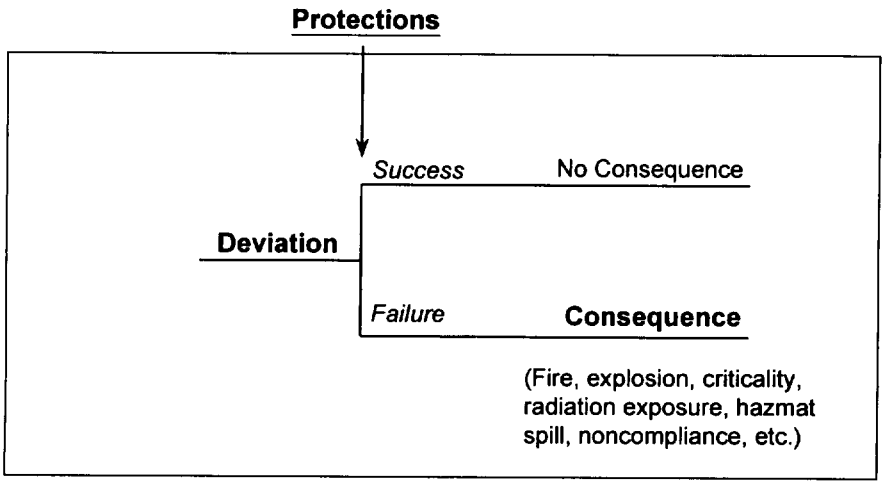
4. *Trace Deviation to Loss Consequences*



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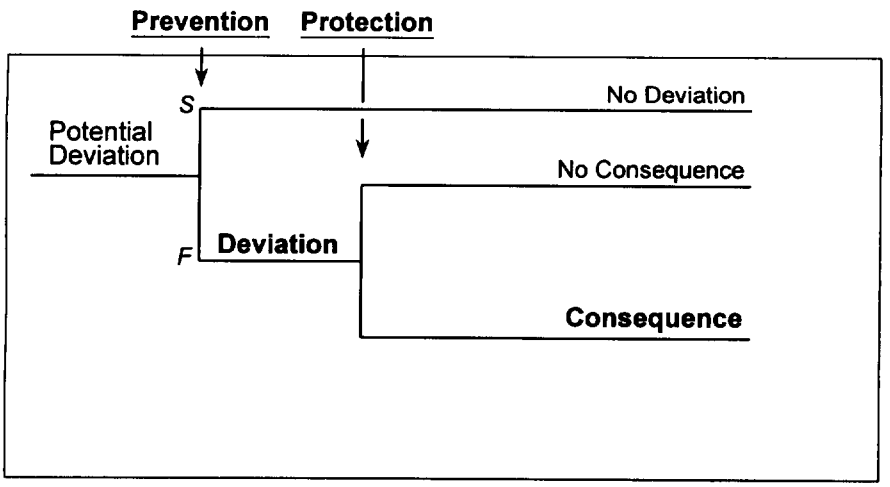
5. *Identify Deviation Prevention Measures*



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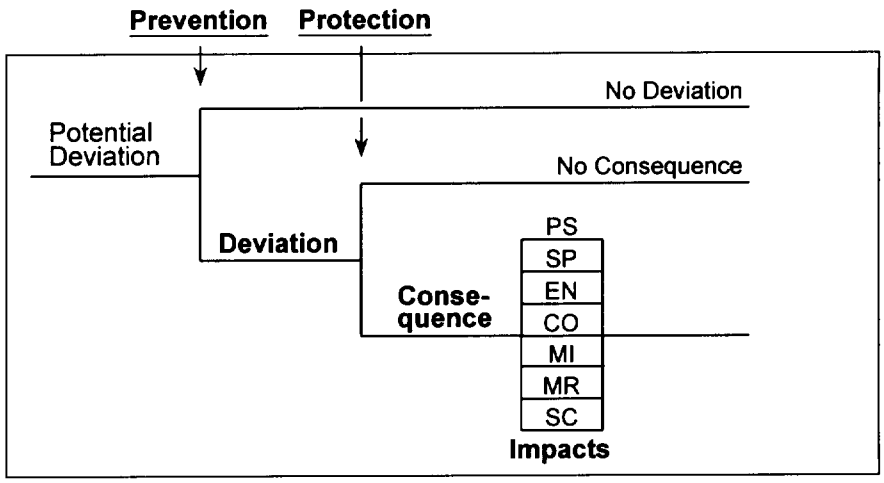
6. *Determine Impact Magnitudes*



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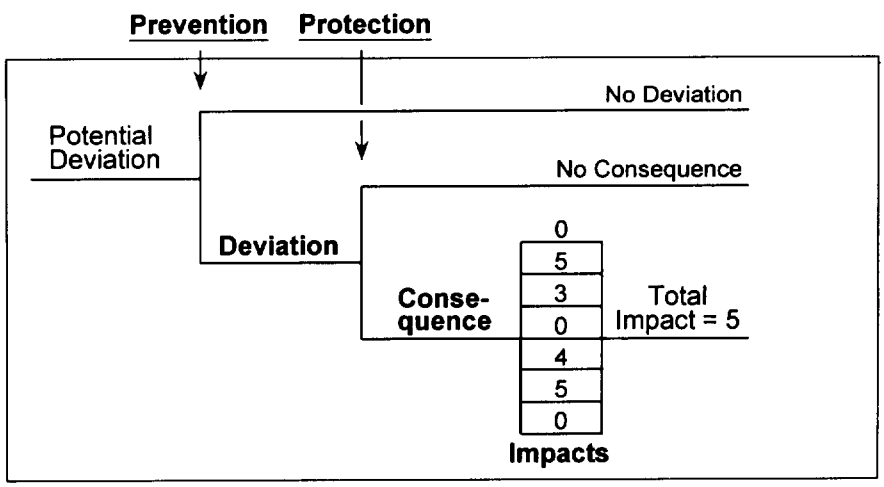
7. *Calculate Total Impact*



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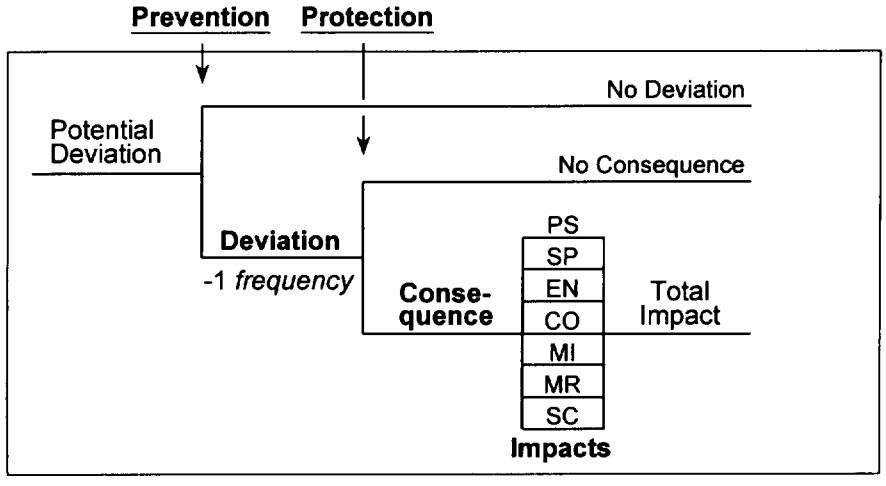
8. *Quantify Deviation Frequency*



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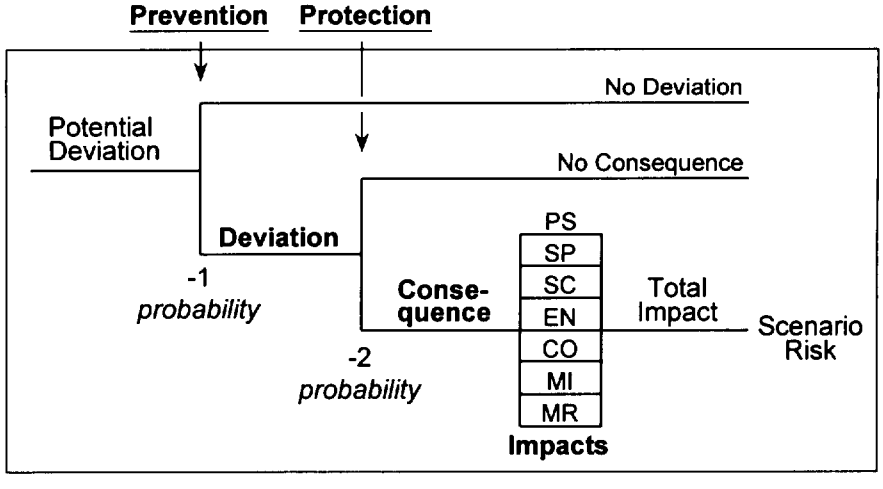
9. *Quantify Prevention, Protection Effectiveness*



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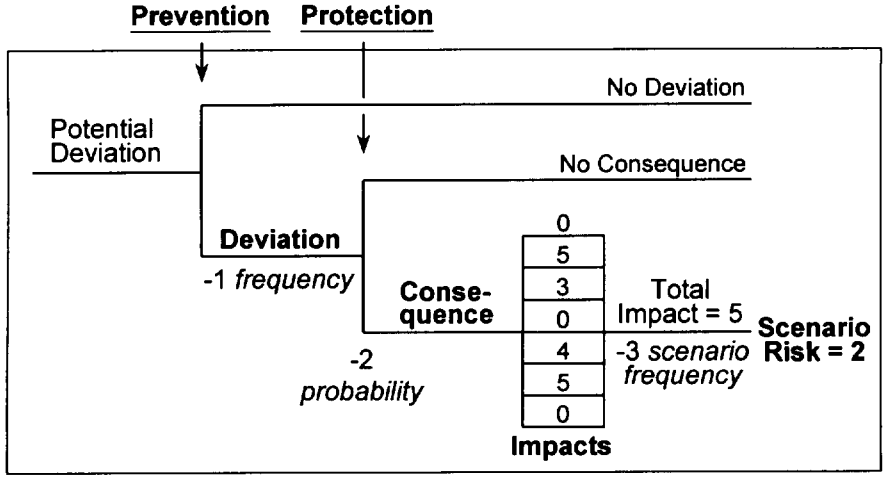
10. *Calculate Scenario Risk*



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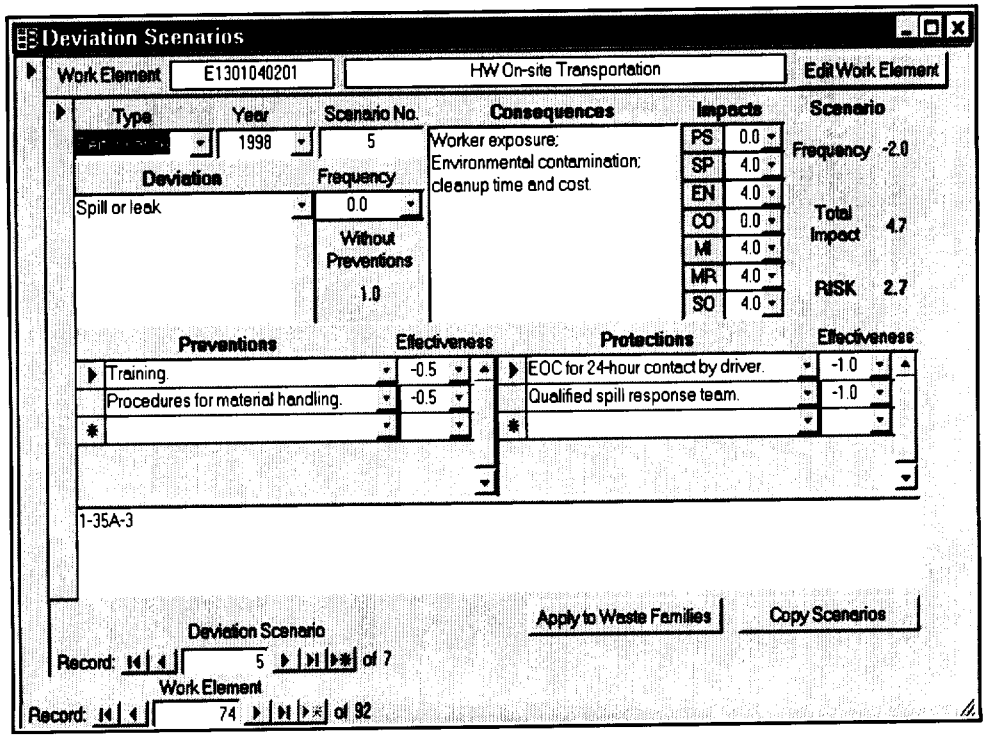

Performance Risk: Summary

- Baseline
- Deviations
- Preventions and Protections
- Impact Magnitudes
- Frequency and Probabilities
- Scenario Risk
- Combine scenario risks to obtain work element performance risk

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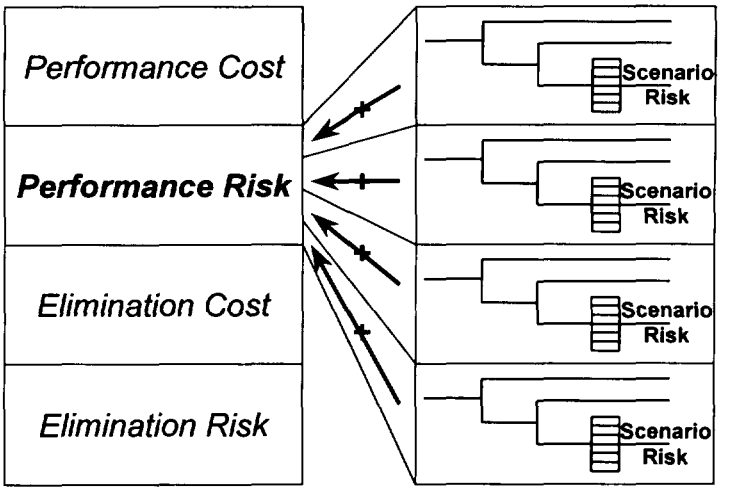
Performance Risk from Scenario Risks



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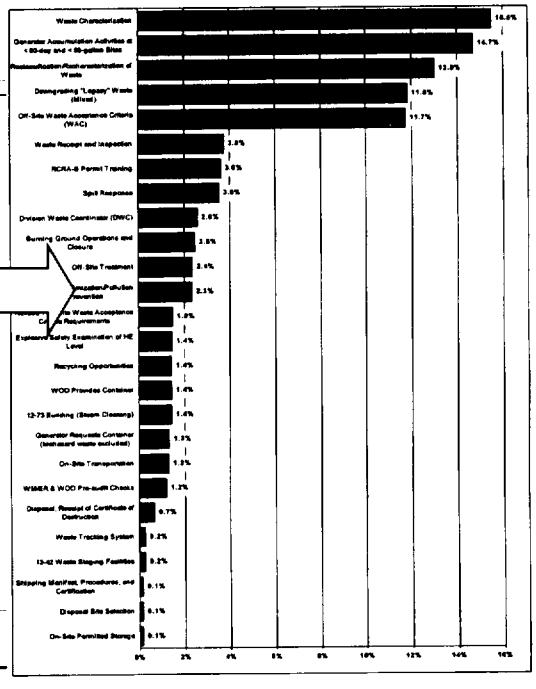
Risk Ranking

- Performance Cost
- Performance Risk
- Elimination Cost
- Elimination Risk



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Delay Cost

WORK ELEMENT e.g., Waste Treatment

- *Performance Cost*
- *Performance Risk*
- ***Delay Cost***
- *Delay Risk Increase*
- *Elimination Cost*
- *Elim. Risk Increase*

= Total expected liability if element is delayed a year

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Delay Risk Increase

WORK ELEMENT *e.g.*, Waste Treatment	*Performance Cost*
	Performance Risk
	Delay Cost
	Delay Risk Increase
	Elimination Cost
	Elim. Risk Increase

= Site-wide risk increase if activity is delayed a year

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Elimination Cost

WORK ELEMENT *e.g.*, Waste Treatment	*Performance Cost*
	Performance Risk
	Delay Cost
	Delay Risk Increase
	Elimination Cost
	Elim. Risk Increase

= Total expected liability if element is eliminated

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Obtaining the Elimination Cost

Performance Cost
Performance Risk
Elimination Cost
Elimination Risk

- Must consider all impacts
- Expected costs and impacts
- Determine magnitude; e.g.,

7	$10,000,000
6	$1,000,000
5	$100,000
4	$10,000

- Can use partial magnitudes

5.5	$300,000

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Elimination Risk Increase

WORK ELEMENT *e.g.*, Waste Treatment	*Performance Cost*
	Performance Risk
	Delay Cost
	Delay Risk Increase
	Elimination Cost
	Elim. Risk Increase

= Site-wide risk increase if activity is eliminated

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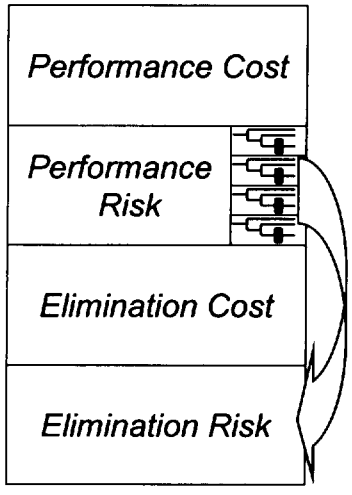
Obtaining the Elimination Risk Increase



- Must consider elimination of *preventions* and *protections*
- Therefore, must have deviation scenarios completed first
- Must also tie preventions and protections to work elements
- Risk increase automatically calculated by database query

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Initiating Events vs Safeguards

- ***Initiating events*** **are the causes of losses**
  - Human error, mechanical failure, external events
  - **Cannot** continue normal operation once occurred
  - Important parameter is the **frequency**
- ***Safeguards*** **are barriers against losses**
  - Preventions, Protections, Mitigations
  - **Can** continue normal operation for a time, even if unavailable
  - Important parameter is the dependent **probability** of being inadequate when needed

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Example: Emergency Relief Device

Consider a fusible plug on a chlorine cylinder.

- **Premature opening of the fusible plug (e.g., due to corrosion) would be an *initiating event***
  - Initiates an accidental event sequence, or scenario
  - Important parameter is the frequency of occurrence
- **Failure of the fusible plug to open when needed would be a *protection* failure**
  - Operation can continue with plug in failed-closed state
  - Important parameter is the probability of failure when needed

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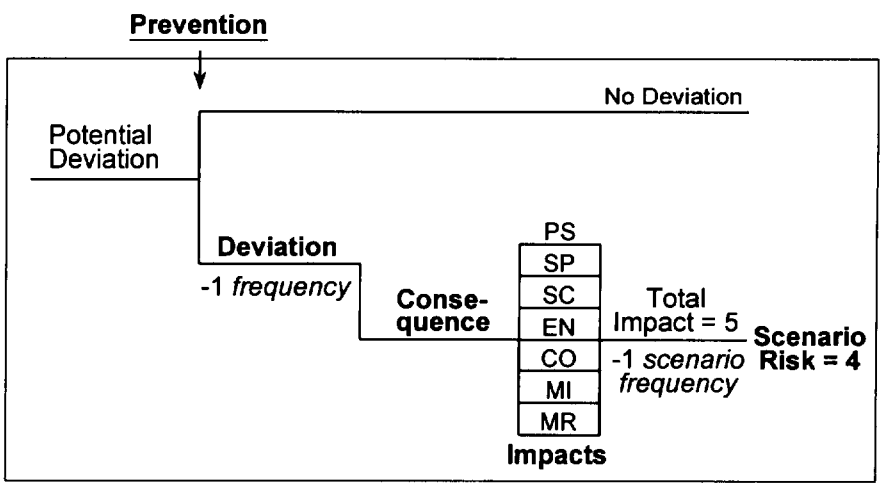
Eliminate Work Element Providing Protection



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MODEL

ANALYZE

PLAN

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PLAN

Looking at one work element at a time:

- Performance Cost+Risk < Elimination Cost+Risk:

Not beneficial to eliminate

- Performance Cost+Risk > Elimination Cost+Risk:

Consider eliminating first

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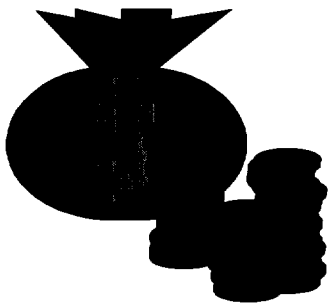
Performance Cost + Performance Risk

WORK ELEMENT *e.g.*, Waste Treatment	
	Performance Cost
	Performance Risk
	Delay Cost
	Delay Risk Increase
	Elimination Cost
	Elim. Risk Increase

} Neither is incurred if this work element is delayed or eliminated



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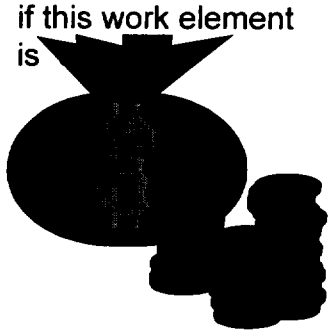
Delay Cost + Delay Risk

WORK ELEMENT *e.g.*, Waste Treatment	
	Performance Cost
	Performance Risk
	Delay Cost
	Delay Risk Increase
	Elimination Cost
	Elim. Risk Increase

} Both are realized if this work element is



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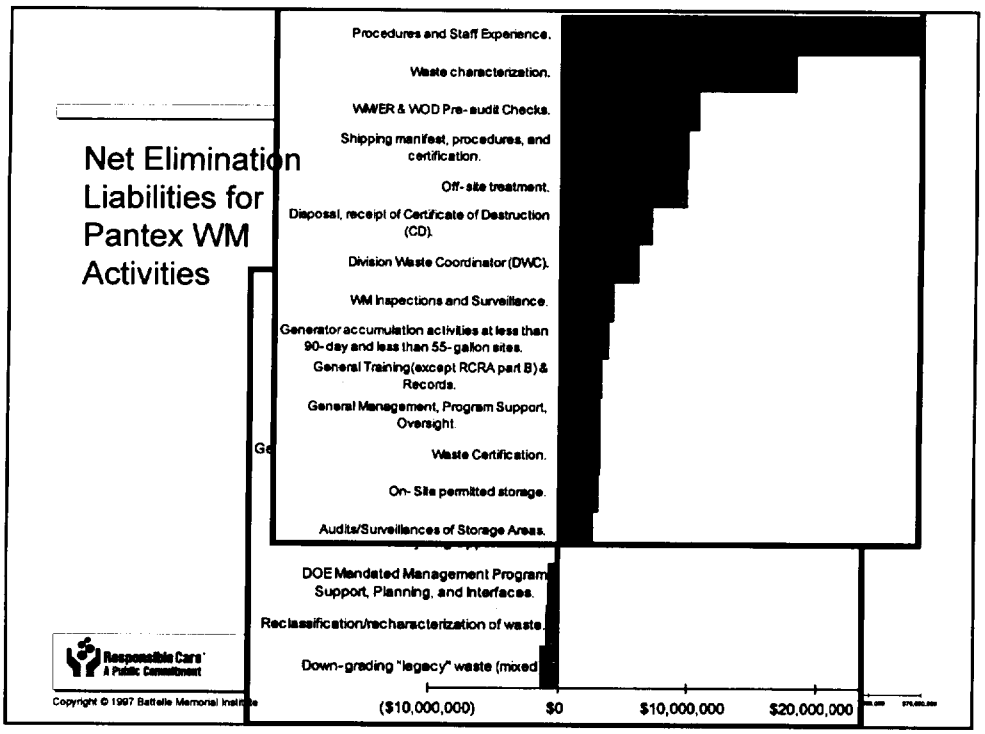

Use of Risk Mapping Results

- Determine/reduce existing risks
- Find what activities may be cut with least impact
- Reallocate resources
- Update MS Project schedules
- Prioritize new projects
- Analyze alternate pathways
- Populate DOE Risk Data Sheets

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Conclusions

A risk mapping process has been employed, featuring:

- Quantitative risk magnitudes
- *Prevention* and *protection* activities considered separately from operational activities
- Integration of ES&H, mission, societal, and $ impacts
- Time-dependent projects combined with on-going activities in the same risk ranking
- Flexibility to consider risks at different organizational levels
- Capability to optimize resources by showing how risks can be managed in the face of decreasing resources

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